# GENERAL AND PHYSIOLOGICAL EFFECTS OF CYANAMID PRODUCTS AND PETROLEUM OILS AS HERBICIDES OR AS PRE-HARVEST TOP-KILLERS FOR LEGUMES

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# GENERAL AND PHYSIOLOGICAL EFFECTS OF CYANAMID PRODUCTS AND PETROLEUM OILS AS HERBICIDES OR AS PRE-HARVEST TOP-KILLERS FOR LEGUMES

A DISSERTATION
SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES
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by
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# SYNOPSIS

## PART I

Under the conditions of this investigation, first year stands of legume crops for seed were successfully weeded with Cyanamid contact herbicides. Some promising results from treatment of young annual weeds in cereal crops were also obtained but the results in this regard are not yet conclusive.

## PART II

Cyanamid contact herbicides were successfully used in pre-harvest treatment of legume seed crops and in some instances increased the yield of seed. Petroleum oils were successfully used for the same purpose. Relative efficiency, availability and costs of chemicals require additional study.

## PART III

There was no apparent translocation of the contact herbicide used in this investigation. No apparent damage resulted to seed germination or crowns of treated perennial legume plants.

Sodium cyanamid (X 5) spray apparently has the same physiological effects on plant root reserves as those following lowered temperatures and top-killing frosts.

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# GENERAL AND PHYSIOLOGICAL EFFECTS OF CYANAMID PRODUCTS AND PETROLEUM OILS AS HERBICIDES OR AS PRE-HARVEST TOP-KILLERS FOR LEGUMES

G. S. Cooper

## PART I

## WEED CONTROL USING CYANAMID CONTACT-KILLING HERBICIDES

### INTRODUCTION

The purpose of this section of the study was to investigate the possibilities of using Cyanamid contact-killing herbicides for the control of weeds in legumes and cereal crops.

At the present time herbicidal chemicals may be divided into two general classifications. These are translocated herbicides and contact herbicides, and it is with the latter class that this portion of the study deals.

Contact herbicides kill only the organ of the plant covered, and therefore are limited mainly to the control of annual weeds, but may be employed for use on perennial weeds where starving or retarding effect is desired.

In northern Alberta the growing of legume crops such as alfalfa and clovers for seed production has become a very important industry, and the control of annual weeds in first year stands of legumes without permanent injury to the crop would be highly desirable. The perennial nature of such legume crops and their susceptibility to existing translocated herbicides makes it seem more advisable to use a contact-killing herbicide for weed control.

In certain localized areas Tartary buckwheat has become a serious problem and threatens to spread over a wide area unless a control can be found. To date this weed in an advanced stagehas proved to be resistant to concentrations of translocated herbicides which may safely be used on cereal crops. For this reason it was thought useful to experiment with contact-killers on Tartary buckwheat and certain other annual weeds which have shown partial or complete resistance to translocated herbicides.

## LITERATURE REVIEW

The principle of general contact herbicides and of selective weed killing with herbicidal sprays has been known for the past 50 years. One of the first substances to be employed for this use was sulfuric acid, as long ago as 1897 it was reported that dilute sulfuric acid would control such broad leafed weeds as mustard and wild radish without injury to the crop plants. Ball and French (4) and Newhall et al (26) reported that up to 95% of such broad leaved weeds may be killed by the application of dilute sulfuric acid to fields of onions, the onions being unharmed because of their vertical growth habit, waxy bloom and concealed growing point. Aslander (3) reported that sulfuric acid kills only the cells it comes in contact with and is not translocated. He reported that during his experiments, humidity and temperature changes had varying effects upon the results obtained. Crafts (8) stated that 1.0 N sulfuric acid or stronger is necessary to kill plants and even at these concentrations the volume of solution used must be sufficient to wet the foliage thoroughly, before favorable results are obtained. The thickness of the cuticle and the age of the leaves treated caused a great variation in the final results obtained. The younger the leaves the more difficult it was to get satisfactory results.

Blackman and Templeman (5) found that the efficiency of sulfuric acid in killing corn, chrysanthanum was improved by a wetting agent. Evans and Martin (11) have shown that the addition of an excess of wetting agent to sprays may lower the amounts of spray retained by the leaf surface. If the toxicant can be readily increased in concentration however, the use of a wetting agent with the same amount of toxicant in a reduced volume of water may save time and labor.

Newhall _et al_ (26) and Crafts (9) reported that the following essentials must be considered when a contact-killer is being used:

(a) age of crop,
(b) temperature,
(c) size of weeds,
(d) sufficient toxicant must be applied to kill the bulk of vegetation desired to be killed, and allow considerable excess for uneveness of application and differences in plant thickness,
(e) spray solution must be distributed so that growing parts of weeds are covered completely,
(f) where vigorous weeds, or grassy weeds are present, the solution must creep down into the crowns to prevent renewal of growth by tillers.

Newhall _et al_ (26) reported that sodium chlorate and Atlacide, two contact herbicides, were very good for control of all growing vegetation, but were unsatisfactory because they

remained in the soil for a long period and stunted the growth of subsequent crops. Sinox, one of the dinitro contact herbicides, was successfully used to control annual weeds in onions, but the margin of safety was very narrow and its use was not recommended.

Litzenberger (22) reports successful use of borax for control of certain weeds in stands of grass or related plants and that this chemical is more effective on light, porous soils.

Newhall et al (26) stated that if calcium cyanamid were applied to wet foliage at the rate of 35 - 80 pounds per acre annual weeds were controlled. Erratic results were obtained however, unless wet foliage was treated. Temporary damage to onion plants often occurred, but full recovery was made in a short time. Lee and Ellis (21) reported that sodium arsenite sprays and calcium cyanamid dusts were effective herbicides in many crops. When sodium arsenite was applied as a spray, very fine droplets gave excessive coverage resulting in considerable damage to the crop plant which, however, showed considerable tolerance when the liquid was applied in larger droplets. They stated that cyanamid dust to be effective, must remain on the plant several days without disturbance by rain or heavy dew. Rain or dew following closely after application of the herbicide resulted in a decrease in the effectiveness of the herbicide. Carew (6) stated that excellent weed control in peas was obtained with calcium cyanamid dust and potassium cyanate (X 1) spray, and that no

harmful residue remained. No approximate rates were quoted. Rademacher (29) reported the use of calcium cyanamid for weed control in both summer and winter cereals at the rates of 135 to 270 pounds per acre.

Robbins _et al_ (32) reported that many cultivated legumes have a thick cuticle and are covered with a waxy bloom and therefore shed most of the spray and are not seriously injured by contact herbicides if concentrations are not too high. It seems therefore that certain of the Cyanamid contact herbicides may be useful in the control of weeds in alfalfa, red clover and alsike clover fields in Alberta. The following tests were carried out to investigate this possibility.

## MATERIALS AND METHODS

Both sprays and dusts containing contact-killing herbicides were employed in this preliminary study. Potassium cyanate (X 1) and sodium cyanamid (X 5) were used. The Tables indicate the rate, form of chemical and gallonage of water used with sprays. The sprays were applied from a knapsack sprayer fitted with a fan nozzle; the dusts spread using a hand pump insecticide duster.

Alfalfa, alsike clover and barley were chosen as experimental material in this study. Weed seeds were sown in fields where it was necessary to ensure an adequate weed growth.

## Alfalfa

Plots of alfalfa 12 ft. x 12 ft., seeded in 1949, were treated in the spring of 1950. Weed seeds were broadcast and raked into the soil before spring germination commenced. Table I, 1, gives the chemicals selected for this experiment.

Table I, 1

| Chemical | Form applied | Rate, lb. per acre | Gallonage/acre where $H_2O$ used |
|---|---|---|---|
| Potassium cyanate (X 1) | Spray | 5-10-15 | 40 |
| Potassium cyanate (X 1) | Dust | 60-80-100 | -- |
| Sodium cyanamid (X 5) | Spray | 40-60-80 | 40 |
| Sodium cyanamid (X 10) | Dust | 60-80-100 | -- |
| Granular cyanamid | Granules | 90-120-150 | -- |
| Special grade cyanamid | Dust | 90-120-150 | -- |

With the exception of granular and special grade cyanamid, the above chemicals were applied to two replicated sets of plots at two different dates. As granular and special grade cyanamid are recommended for pre-emergence weed control only, it is practicable to apply these chemicals at one date only, unless cultivation is carried out just prior to application. In this experiment no cultivation was used, so when the second replicate was treated at a later date, potassium cyanate (X 1) blend was substituted for granular and special grade cyanamid.

The chemicals were applied to Rep. 1 on May 5, 1950, during initial stages of plant growth: Rep. 2 was treated June 15, 1950, when the weeds and alfalfa were commencing to flower.

Growth was very slow because of the extremely adverse conditions experienced during the spring of 1950, At the date of the first application the soil moisture was very low. Temperatures for the week following application remained relatively low, averaging a daily high of about 58°F.

At the second date of application the reserve soil moisture was still very low. For ten days following application the average daily high was approximately 76°F. Growth of weeds and alfalfa was below normal for this time of year.

## Alsike Clover

In 1949 plots of alsike clover 9 ft. x 9 ft. were selected from a field of alsike clover sown in 1948 at the University of Alberta. A simple randomized block design consisting of four replicates was used.

Table I, 2, gives the chemicals, rates and gallonages of water used in this test.

Table I, 2

| Chemical | Form applied | Rate, lb. per acre | Gallonage/acre where $H_2O$ used |
|---|---|---|---|
| Potassium cyanate (X 1) | Spray | 10-20-25 | 40 |
| Potassium cyanate (X 1) | Dust | 60-80-100 | -- |
| Potassium cyanate (X 1) + Vatsol K | Spray | 10-20-25 | 40 |
| Sodium cyanamid (X 5) | Spray | 60-80-100 | 40 |

In the experiments where Vatsol K (2 g.) was added, it was used as a spreader to test the possibilities of applying a spreader or wetting agent in order to reduce the amount of chemical needed to achieve the desired results.

The chemicals were applied August 26, 1949. The weather was sunny, clear and dry. The average daily temperature for the following seven days was 72°F. No rain or dew fell during this period. The first seed set of clover was ripe and the second seed set was just maturing. The weeds were in all stages of growth.

## Barley

Two fields of Olli barley were sown May 5, 1950. To the barley seed for one field, Tartary and wild buckwheat seeds were added. Plots 10 ft. x 10 ft. were marked out in these fields as soon as the barley appeared. The plots without the added Tartary and wild buckwheat were included to permit investigation of possible delay in maturity and reduction in yield resulting from the application of a contact herbicide.

Table I, 3, gives the chemicals, rates and gallonages applied where sprays were used.

Table I, 3

| Chemical | Form applied | Rate, lb. per acre | Volume applied per acre |
|---|---|---|---|
| Potassium cyanate (X 1) | spray | 8-12 | 40 |
| Sodium cyanamid (X 5) | spray | 40-60 | 40 |
| Pot. cyanate (X 1) + 2 gals. per acre, 2,2,4 trimethylpentane* | fine mist | 4-8 | 40 |
| Pot. cyanate (X 1) + 4 gals. per acre, 2,2,4 trimethylpentane* | fine mist | 4-8 | 40 |
| Pot. cyanate (X 1) + 2 gals. per acre, 2,2 Dimethyl Butane* | fine mist | 4-8 | 40 |
| Pot. cyanate (X 1) + 4 gals. per acre, 2,2 Dimethyl Butane* | fine mist | 4-8 | 40 |
| Sod. cyanamid (X 5) + 2 gals. per acre 2,2,4 trimethylpentane * | fine mist | 4-8 | 40 |
| Sod. cyanamid (X 5) + 4 gals. per acre, 2,2,4 trimethylpentane* | fine mist | 4-8 | 40 |
| Sod. cyanamid (X 5) + 2 gals. per acre, 2,2 Dimethyl Butane* | fine mist | 4-8 | 40 |
| Sod. cyanamid (X 5) + 4 gals. per acre, 2,2 Dimethyl Butane* | fine mist | 4-8 | 40 |

* One gram of Dreft added as an emulsifying agent.

The 2,2,4 trimethylpentane has a B.P. of 99.3°C. and is considered as a heavy oil fraction. It contained few aromatic hydrocarbons. The 2,2 dimethyl butane has a B.P. of 49.7°C. and is considered a light oil fraction. It contained a high percentage of aromatic hydrocarbons.

The chemicals were applied June 12, 1950. The sprays were applied with a knapsack sprayer, while the fine mists were applied with a paint spray gun attached to a knapsack sprayer tank used as the source of compressed air.

The weather conditions were extremely adverse resulting in the germination of very little buckwheat. The daily high for the following week was approximately 85°F.

## EXPERIMENTAL RESULTS

### Alfalfa

The combined results of the treatments of Reps. 1 and 2 are shown in Table I, 4. Table I, 5, gives the actual weed counts per square foot.

The following tables I, 4 to I, 6, illustrate results of yearly trials of 1949 in which various chemicals used in various ways for weed control purposes.

Table I, 4

| Chemical | Rate, lb./ acre | Weed control* | Alfalfa damage | Comments |
|---|---|---|---|---|
| Pot. cyanate (X 1) dust | 60 | Poor | Nil | Little promise |
| | 80 | Fair | Nil | Control of two leaf weeds |
| | 100 | Good | Nil | 50% weed control |
| Pot. cyanate (X 1) spray | 5 | Poor | Nil | Rate is too low |
| | 10 | Very good | Some chlorosis | Has promise |
| | 15 | Excellent | Heavy chlorosis | Very good here |
| Sod. cyanamid (X 5) dust | 60 | Poor | Nil | Not heavy enough rate |
| | 80 | Very good | Leaf spotting | Shows promise |
| | 100 | Excellent | Heavy damage | Some top damage noted |
| Sod. cyanamid (X 5) spray | 40 | Fair | Basal leaf damage | Good |
| | 60 | Excellent | Tip yellowing | May delay flowering |
| | 80 | Excellent | Heavy damage | Too much damage |
| Granular cyanamid | 90 | Poor | Nil | Not high enough rate |
| | 120 | Poor | Nil | Not high enough rate |
| | 150 | Fair | Nil | " heavy enough rate |
| Special grade cyanamid | 90 | Poor | Nil | Not heavy enough rate |
| | 120 | Fair | Nil | Not heavy enough rate |
| | 150 | Very good | Nil | Need more uniform appl |
| Pot. cyanate (X 1) blend dust | 60 | Fair | Nil | Need more uniform appl |
| | 80 | Very good | Leaf spotting | Need more uniform appl |
| | 100 | Excellent | Heavy damage | Need more uniform appl |

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* Weeds controlled included red root pigweed, lamb's quarters, common plantain, purslane, common groundsel, spear-leaf goosefoot, hawksbeard, night-flowering catchfly, wild mustard and ball mustard.

Table I, 5

| Chemical | Rate | Total weeds killed | | Total weeds | | Remarks |
|---|---|---|---|---|---|---|
| | | Rep.1 | Rep.2 | Rep.1 | Rep.2 | |
| Potassium cyanate (X 1) dust | 1 | 12 | 16 | 49 | 56 | Poor results |
| | 2 | 29 | 32 | 33 | 39 | Good results |
| | 3 | 31 | 28 | 35 | 32 | Very good results |
| Potassium cyanate (X 1) spray | 1 | 17 | 21 | 39 | 45 | Poor results |
| | 2 | 22 | 31 | 43 | 39 | Good results |
| | 3 | 43 | 39 | 43 | 41 | Excellent results |
| Sodium cyanamid (X 5) dust | 1 | 19 | 14 | 36 | 42 | Poor results |
| | 2 | 46 | 26 | 56 | 43 | Very good results |
| | 3 | 37 | 45 | 37 | 45 | Excellent results |
| Sodium cyanamid (X 5) spray | 1 | 32 | 24 | 52 | 43 | Fair results |
| | 2 | 29 | 37 | 29 | 37 | Excellent results |
| | 3 | 33 | 23 | 33 | 23 | Excellent results |
| Granular cyanamid | 1 | -- | -- | 42 | 54 | Poor results |
| | 2 | -- | -- | 63 | 29 | Poor results |
| | 3 | -- | -- | 21 | 19 | Good results |
| Special grade cyanamid | 1 | -- | -- | 37 | 28 | Poor results |
| | 2 | 16 | 19 | 42 | 35 | Fair results |
| | 3 | 28 | 32 | 30 | 35 | Very good results |
| Potassium cyanate (X 1) dust + sticker | 1 | -- | 29 | -- | 43 | Fair results |
| | 2 | -- | 23 | -- | 29 | Very good result |
| | 3 | -- | 41 | -- | 44 | Excellent result |
| CHECK | | | | 55 | 51 | |

The results show that in general the sprays appear to be more effective than the dusts for weed control. The method of applying dusts resulted in a very uneven application so the contrast in results may have been partially attributable to the better coverage from sprays.

The chemical applied at an excessive rate retarded the growth of the alfalfa but even at this very high rate no apparent injury resulted. Potassium cyanate (X 1) spray at 10 and 15 pounds per acre and sodium cyanamid (X 5) spray at 60 pounds per acre effectively controlled young weeds, including common groundsel, red root pigweed, lamb's quarters, spear-leaf goosefoot, hawksbeard, night-flowering catchfly, ball mustard and wild mustard, without apparent damage to the alfalfa crop.

## Alsike Clover

The results of this test as shown in Table I, 6, again indicate that in general sprays were more effective than dusts. It is apparent however, that in controlling weeds in alsike clover, application by either means should be made before the weeds reach the flowering stage.

Table I, 6

| Chemical | Rate, lb./acre | Weed control* |  |  |  | Comments |
|---|---|---|---|---|---|---|
|  |  | Rep. 1 | Rep. 2 | Rep. 3 | Rep. 4 |  |
| Potassium cyanate (X 1) spray | 10 | Good | Good | Good | F.good | Older weeds only partially killed. |
|  | 20 | V.good | V.good | V.good | Good | Very good. |
|  | 25 | Ex. | Ex. | Ex. | Ex. | This rate excessive. |
| Potassium cyanate (X 1) dust | 60 | Poor | Poor | Poor | Poor | Of little value here. |
|  | 80 | Poor | Poor | Fair | Poor | Generally poor. |
|  | 100 | Fair | Poor | Fair | Poor | Very spotty killing. |
| Potassium cyanate (X 1) blend dust | 60 | Poor | Poor | Poor | Poor | This rate is too low. |
|  | 80 | Fair | Good | Fair | Good | Little use for older weeds. |
|  | 100 | V.good | Good | V.good | V.good | Very good young weed control. An evener coverage would help. |
| Sodium cyanamid (X 5) spray | 60 | Ex. | Ex. | Ex. | Ex. | Not too effective on older weeds. |
|  | 80 | Ex. | Ex. | Ex. | Ex. |  |
|  | 100 | Ex. | Ex. | Ex. | Ex. | Too heavy a rate here. |
| Sodium cyanamid (X 5) spray + Vatsol K | 60 | Ex. | Ex. | Ex. | Ex. |  |
|  | 80 | Ex. | Ex. | Ex. | Ex. |  |
|  | 100 | Ex. | Ex. | Ex. | Ex. | Too heavy a rate here. |

Table I, 6 (Continued)

| Chemical | Rate, lb./ acre | Weed control* | | | | Comments |
|---|---|---|---|---|---|---|
| | | Rep. 1 | Rep. 2 | Rep. 3 | Rep. 4 | |
| Sodium cyanamid (X 10) dust | 80 | Poor | Poor | Poor | Poor | Of little value here. |
| | 100 | Fair | Good | Good | Good | Poor, large weed control. |
| | 120 | V.good | Good | V.good | V.good | Very good on younger weeds. |
| Sodium cyanamid (X 10) dust + Vatsol K | 40 | Fair- | Fair | Fair | Fair | Poor, older weed control. |
| | 60 | Good | Good | Good | V.good | Good, young weed control. |
| | 100 | V.good | V.good | V.good | V.good | |
| Potassium cyanate (X 1) spray + Vatsol K | 10 | V.good | V.good | V.good | V.good | Very good weed control |
| | 20 | Ex. | Ex. | Ex. | Ex. | |
| | 25 | Ex. | Ex. | Ex. | Ex. | |

* Weeds encountered were: lamb's quarters, red root pigweed, common plantain, purslane, common groundsel, spear-leaf goosefoot, hawksbeard, night-flowering catchfly, wild mustard, ball mustard.

Potassium cyanate (X 1) spray at 20 pounds per acre and sodium cyanamid (X 5) spray at 60 pounds per acre gave excellent control of young weeds with very little apparent permanent injury to the alsike clover. The weeds encountered were the same as those listed previously in alfalfa experiments. The addition of one gram of Vatsol K increased the efficiency of potassium cyanate (X 1) spray, thus indicating that a reduction in the amounts of this chemical needed may prove to be feasible when used as a spray.

The rates of sodium cyanamid (X 5) spray were too high to show differences when Vatsol K was added.

## Barley and Buckwheat

### Observations Five Days After Treatment

Potassium cyanate (X 1) spray at eight and 12 pounds per acre resulted in very good control of all young annual weeds present. The 12 pound rate resulted in a complete top-killing of Tartary and wild buckwheat in the two-leaf stage. Older plants

showed only upper leaf necrosis. There was also some evidence of leaf burning on the lower barley leaves.

The compound X 5 at 40 and 60 pounds per acre gave complete control of young annual weeds. The buckwheat in the 2-4 leaf stage showed extensive leaf-killing. The 60 pound rate resulted in a great deal of necrosis in the barley.

Potassium cyanate and sodium cyanamid, with the addition of oil, showed a great deal of injury to the barley as well as to the weeds. In the tests where oil was used, the addition of one gram of Dreft per plot may have been partially responsible for the increased injury observed.

## Observations 14 Days After Treatment

Potassium cyanate (X 1) spray at eight pounds per acre resulted in a complete kill of the very young annual weeds except buckwheat. The buckwheat showed evidence of leafing from the lower nodes. The barley had apparently made complete recovery from the initial damage observed. Potassium cyanate at the 12 pound rate gave complete control of the young annual weeds including buckwheat in the 2-4 leaf stage. Older buckwheat plants were budding from the lower nodes. The leaf edges of the barley were necrotic, while many of the lower leaves showed chlorotic spotting.

Sodium cyanamid (X 5) spray at 40 pounds per acre caused a general yellow cast to the entire plots treated. There were no signs of recovery of the buckwheat treated in the two-leaf stage. Older plants were stunted, but had commenced leafing from the lower nodes.

Sodium cyanamid (X 5) spray at 60 pounds per acre resulted in a very definite yellow cast of the plots treated. There was considerable killing of the lower leaves of the barley and chlorosis of the upper leaves. Young buckwheat plants were severely burned and showed no signs of recovery. The older buckwheat plants developed a marked thickening and stunting of the basal parts of the stem. At this time there was a definite indication of a retarding effect on the growth of the barley.

As judged by the definite retardation and severe damage to the barley, potassium cyanate (X 1) and sodium cyanamid (X 5) with the addition of Dreft and oil apparently are insufficiently selective for this type of weed control.

## Observations 21 Days After Treatment

Heavy rainfalls 16 and 17 days after application of the chemicals resulted in a new growth of weeds, buckwheat and a second growth of barley, thus rendering further observations and results of very little value.

## DISCUSSION AND CONCLUSIONS

From the results obtained in the experimental trials for control of weeds in alfalfa and alsike clover using Cyanamid contact-killing herbicides, sprays appear to be more efficient for this purpose than do dusts. Because of the relatively inefficient method of applying dusts however, it is very difficult to evaluate fully their potential values in this type of work.

Potassium cyanate (X 1) blend dust, and sodium cyanamid (X 10) dust show promise for control of young annual weeds if even coverage can be obtained. Granular cyanamid, special grade cyanamid and potassium cyanate (X 1) dust show very little promise for this work. Potassium cyanate (X 1) spray at 10 and 15 pounds per acre resulted in very good control of annual weeds. Sodium cyanamid (X 5) spray at 60 pounds per acre applied in 40 gallons of water per acre, resulted in complete control of all annual weeds provided they had not reached the flowering stage. In spite of a definite yellowing of the alfalfa and alsike clover following treatment, no apparent permanent damage occurred and full recovery of the crop was noted within a few days. It is therefore thought that this method of weed control should be very satisfactory in controlling annual weeds in first year stands of legume crops in northern Alberta.

The use of contact-killing herbicides for the control of Tartary buckwheat and other annual weeds needs further experimental trials. Sodium cyanamid at 40 and 60 pounds per acre shows some promise for selectively controlling Tartary buckwheat and purslane if treated in the 2-4 leaf stage. However, quantitative final yield determinations on the barley must be determined before any definite decisions can be reached.

# PART II

## CHEMICAL TOP-KILLING OF LEGUMES WITH CYANAMID CONTACT HERBICIDES AND CERTAIN PETROLEUM OILS

### INTRODUCTION

The purpose of this phase of the work was to investigate the possibilities of using Cyanamid contact herbicides and certain petroleum oils containing a high percentage of aromatic hydrocarbons for top-killing of legumes and for delaying the dehiscence of birdsfoot trefoil pods.

Since contact herbicides kill only the organ of the plant covered, there is a possibility that some of these herbicides may be employed for the pre-harvest top-killing of legumes, thus assisting in the harvesting of such crops as alfalfa, red clover, alsike clover and birdsfoot trefoil. If enough of the top growth of the legume plant could be killed without damage to the crown or root, direct combining could be carried out, thus preventing loss through

excessive handling and shattering. The chemical used for this purpose must not cause injury to the crown or root or to the seeds within the pods.

By application of a contact herbicide to prepare the crop for combining, the farmer should be able to control to some extent the time of harvest and thus aid in the planning of harvest operations during the busy season. Because such herbicides act by direct contact only, attention has been given to the supplementary use of stickers and spreaders in attempts to obtain greater foliage coverage and therefore a more thorough top-killing.

## LITERATURE REVIEW

The perennial habit of alfalfa, red clover, alsike clover and birdsfoot trefoil makes it preferable that the top-killing chemical used be of the contact type rather than the translocated type. Any translocation of the chemical may cause death of crown or root of the plant. It is necessary, however, that the herbicide reach the parts of the plant that must be killed.

Aslander (3), using sulfuric acid as a contact herbicide for general weed control, reported that the acid penetrated the cuticle rapidly and caused death to the cells contacted, yet no translocation was evident. In this work humidity and temperature changes had varying effects upon the results obtained. Crafts (7) stated that 1.0 N sulfuric acid or stronger concentrations were needed to kill plants and even at these strengths the volume of solution used must be sufficient to wet the foliage thoroughly before favorable resultswere obtained. Guy (16) reported successful defoliation of thousands of acres of cotton by the application of calcium cyanamid resulting in a better grade of cotton and a definite schedule of cotton picking. Guy stated however, that a uniform and complete coverage of all foliage is absolutely essential with all known defoliants, either when used as dry dusts or as liquid sprays. Efficient machines and careful operators are also essential. Where sprays are used a true mist is not desirable because mists do not provide sufficient penetration whereas too coarse a spray results in uneven coverage.

Stiver and Johson (34) reported excellent cotton leaf killing using 25 pounds sodium cyanamid (X 5) spray at 25 pounds per acre. Morris and Cowley (25) reported that climatic conditions are a very important factor in the use of contact herbicides. In very dry areas where no dews occur, sprays are more efficient

than dusts. They reported that potassium cyanate (X 1) spray at 11.25 pounds per acre was a very efficient killer of cotton leaves.

Thaxton and Jones (35) reported that in experimental trials on cotton defoliation, potassium cyanate (X 1) spray at 12 pounds per acre and sodium cyanamid (X 5) spray at 50 pounds per acre gave excellent kills of cotton leaves. They also reported that the addition of 1% Vatsol as a wetting agent greatly increased the efficiency of the chemical. Results of their tests in 1948 indicate that in drouthy years when no dew is present, sprays are needed, and that sodium cyanamid (X 5) spray consistently gave the best results. Where high concentrations of sprays were needed there was little difference in varietal response to the chemical, and a uniform killing was achieved. Although promising when applied at times of heavy dew, the hygroscopic dusts, sodium cyanamid (X 10), were not dependable during periods of low humidity.

Rich (30) reported that in the top-killing of potato-vines, there was a marked difference in the rapidity and extent of the top-killing which took place following the application of the many commercial chemicals available at the time of experimentation. There was considerable injury to the xylem and phloem in the tubers when fast acting chemical herbicides were used. It was suggested that the damage to the tuber was not caused by the

herbicide, but by a substance already present in the plant and induced to migrate to the tubers. On the other hand, calcium cyanamid, which required several days for completion of action, resulted in very little tuber damage. Kraus and Dietz (19) reported that the use of one pound of ammonium sulfate in one gallon of water applied at 100 gallons per acre gave satisfactory top-killing of Bliss Triumph vines but not of Netted Gem vines. Apparently there are varietal differences in the response of potatoes to such treatments.

There is very little literature with reference to the pre-harvest top-killing of grain and legume seed crops. Available reports from south eastern United States (2), however, indicate that dinitro-compounds with diesel oil have been applied from the air with considerable success on flax and alfalfa during the past three years.

## SUMMARY OF PROCEDURE AND RESULTS

The cyanamid products used in this part of the study were applied as sprays or dusts. Knapsack sprayers were used to apply sprays to experimental plots, while a high gallonage Green Cross sprayer was used for field application. A hand pump insecticide duster was used to apply dusts to experimental plots while a T & T "Electronic" duster was used to apply dusts in field work. Plots 10 ft. by 10 ft. were used in small scale trials and the field tests involved 0.6 acre plots. In 1948 alfalfa and red clover were used as experimental material while in 1949 alfalfa and alsike clover were treated. In 1950 alfalfa, alsike clover, red clover and birdsfoot trefoil were included in the experimental trials. The birdsfoot trefoil was treated in an effort to find a method whereby the mechanism controlling dehiscence of the pod could be controlled, thus preventing the shattering of the seed prior to harvesting. At the present time there is no satisfactory method of harvesting this seed crop because of the explosive nature of the pods.

## Alfalfa, 1948

The following tables II, 1 to II, 13, indicate the results of yearly trials in which various chemicals used in various ways as preharvest top-killers for species indicated.

### Table II, 1

### Plot Trials

| Chemical | Rate, lb./ acre | Gallons of $H_2O$ applied /acre | % top-killing |
|---|---|---|---|
| **Sprays** | | | |
| Potassium cyanate (X 1) | 40 | 200 | 80 |
| | 40 | 400 | 80 |
| Potassium cyanate + 1 g. soap | 40 | 200 | 95 |
| | 40 | 400 | 95 |
| Potassium cyanate + 1 g. casein | 40 | 200 | 100 |
| | 40 | 400 | 100 |
| Potassium cyanate (X 1) | 60 | 200 | 100 |
| | 60 | 400 | 100 |
| Potassium cyanate + 1 g. soap | 60 | 200 | 100 |
| | 60 | 400 | 100 |
| Potassium cyanate + 1 g. casein | 60 | 200 | 100 |
| | 60 | 400 | 100 |
| Sodium cyanamid (X 5) | 60 | 200 | 90 |
| | 60 | 400 | 90 |
| Sodium cyanamid + 1 g. soap | 60 | 200 | 95 |
| | 60 | 400 | 95 |
| Sodium cyanamid (X 5) | 100 | 200 | 100 |
| | 100 | 400 | 100 |
| Sodium cyanamid + 1 g. soap | 100 | 200 | 100 |
| | 100 | 400 | 100 |

Table II, 1 (Continued). Plot Trials

| Chemical | Rate, lb./acre | Gallons of $H_2O$ applied /acre | % top-killing |
|---|---|---|---|
| Dusts | | | |
| Calcium cyanamid | 150 | - | 5 |
| | 200 | - | 10 |
| Monosodium cyanamid | 75 | - | 5 |
| | 100 | - | 5 |
| | 150 | - | 10 |
| Sodium cyanamid (X 10) | 50 | - | 10 |
| | 75 | - | 15 |
| | 100 | - | 25 |

Red Clover, 1948

Table II, 2

Field Trials

| Chemical | Rate, lb./acre | Gallons of $H_2O$ applied /acre | % top-killing |
|---|---|---|---|
| Sprays | | | |
| Potassium cyanate (X 1) | 20 | 4½ | 65 |
| Potassium cyanate + soap, 1 lb./acre | 20 | 9 | 90 |
| Sodium cyanamid (X 5) | 80 | 40 | 100 |
| Sodium cyanamid + soap, 1 lb./acre | 100 | 60 | 100 |
| Dusts | | | |
| Potassium cyanate (X 1) | 80 | - | 10 |
| Sodium cyanamid (X 10) | 40 | - | 5 |

## Discussion

In the top-killing of alfalfa, potassium cyanate (X 1) spray applied at 40 pounds per acre gave satisfactory results and the addition of soap and casein improved the herbicidal action. It is evident that the rate of 20 pounds per acre is in excess of that actually needed to obtain satisfactory results. Similarly the 60 pound rate was higher than necessary, consequently the addition of soap and casein to such treatments did not visibly affect the amount of top-killing obtained.

Sodium cyanamid (X 5) spray at 60 pounds per acre resulted in a satisfactory kill whose efficiency was only slightly increased by the addition of soap. The 100 pound rate resulted in a complete top-killing and the addition of casein and soap was superfluous in this case.

The dusts used in this experiment did not give satisfactory results.

In field trials with alsike clover, Table II, 2, the potassium cyanate (X 1) spray at 20 pounds per acre applied at 4½ gallons per acre did not provide sufficient coverage to completely kill the top growth. When 20 pounds of the chemical were applied at nine gallons per acre with the addition of soap, an increase in the amount of killed vegetation was noted, but the lower leaves

and branches which were not covered resulted in a considerable amount of basal green material.

Sodium cyanamid (X 5) spray at 80 and 100 pounds per acre resulted in a complete top-killing and indicated that the rates used were in excess of the amount of chemical needed to obtain satisfactory results.

Alfalfa, 1949

Table II, 3

Plot Trials

| Chemical | Rate, lb. chemical in 40 gal. $H_2O$/acre | % top-killing |
|---|---|---|
| Potassium cyanate (X 1) spray | 10 | 50 |
| | 20 | 70 |
| | 25 | 90 |
| Sodium cyanamid (X 5) spray | 60 | 90 |
| | 80 | 95 |
| | 100 | 100 |

## Alsike Clover, 1949

### Table II, 4

### Plot Trials

| Chemical | Rate, lb./ acre | Gallons of $H_2O$ applied /acre | % top-killing |
|---|---|---|---|
| Potassium cyanate (X 1) spray | 10 | 40 | 30 |
| | 20 | 40 | 60 |
| | 25 | 40 | 80 |
| Potassium cyanate + Vatsol K ( 1 g.) spray | 10 | 40 | 60 |
| | 20 | 40 | 85 |
| | 25 | 40 | 90 |
| Potassium cyanate (X 1) blend dust | 60 | -- | 10 |
| | 80 | -- | 30 |
| | 100 | -- | 60 |
| Potassium cyanate (X 1) dust | 60 | -- | 10 |
| | 80 | -- | 12 |
| | 100 | -- | 20 |
| Sodium cyanamid (X 5) spray | 60 | 40 | 60 |
| | 80 | 40 | 80 |
| | 100 | 40 | 100 |
| Sodium cyanamid + Vatsol K (1 g.) spray | 60 | 40 | 80 |
| | 80 | 40 | 95 |
| | 100 | 40 | 100 |
| Sodium cyanamid (X 10) dust | 80 | -- | 35 |
| | 100 | -- | 50 |
| | 120 | -- | 65 |
| Sodium cyanamid (X 10) dust + Vatsol K (1 g.) | 80 | -- | 40 |
| | 100 | -- | 60 |
| | 120 | -- | 70 |

Table II, 5

Field Trials

| Chemical | Rate, lb./ acre | Gallons of $H_2O$ applied /acre | % top-killing |
|---|---|---|---|
| Potassium cyanate (X 1) spray | 12 | 60 | 60 |
| Potassium cyanate (X 1) dust | 60 | -- | 15 |
| Sodium cyanamid (X 5) spray | 60 | 60 | 95 |
| Sodium cyanamid (X 10) dust | 60 | -- | 20 |

## Discussion

From Tables II, 3 and II, 4, it can be seen that potassium cyanate (X 1) spray at 20 pounds per acre caused sufficient top-killing to permit direct combining. A more complete top-killing resulted from the use of higher rates, but it is doubtful if this increase was great enough to warrant the extra cost of material. The addition of a spreader permitted a reduction in the amount of chemical necessary to achieve desired results.

The saving was one-half the amount of potassium cyanate necessary when no spreader was used.

Sodium cyanamid (X 5) spray at 60 pounds per acre was sufficient to bring about satisfactory results. The addition of a spreader to this compound also greatly increased its efficiency.

Potassium cyanate (X 1) blend dust and sodium cyanamid (X 10) dust at rates of over 100 pounds per acre resulted in satisfactory top-killing of the older growth of alfalfa, but did not control the younger second growth as well as the sprays did.

Analysis of variance carried out on the yields of the plots given in Table II, 3, indicated that there was no significant difference between the yields of the swathed plots and the yields of the treated plots.

The analysis of variance table shown below is for alfalfa seed yield data for the experiment listed in Table II, 3.

| Variance due to | D.F. | Sums squares | Mean square | F. value | 5% level |
|---|---|---|---|---|---|
| Treatment | 6 | 353.85 | 58.975 | 0.538 | 2.7 |
| Reps. | 13 | 224.03 | 74.676 | 0.681 | 3.16 |
| Error | 18 | 1974.03 | 109.668 | | |
| TOTAL | 27 | 2551.91 | | | |

$$\text{M.S.D.} = \frac{\sqrt{109.688} \times \sqrt{2} \times 2}{\sqrt{4}} = 14.77 \text{ g.}$$

Under the conditions of these tests there was apparently no significant increase or loss of alfalfa seed resulting from the treatment. The pre-harvest treatment would however permit direct combining and thus reduce the risk of loss which is always present when swathing is employed or when harvesting is postponed until after a killing frost. Large losses often result when high winds carry away swathed material and losses can also occur when the killing frost is followed by heavy snows which may delay harvesting operations indefinitely.

Potassium cyanate (X 1) spray at 12 pounds per acre killed sufficient of the top growth of alsike clover to permit direct combining of the strips treated. This chemical required several days longer for effective action than did the sodium cyanamid (X 5) spray at 60 pounds per acre. The latter was very rapid in its action and resulted in satisfactory top-killing of alsike clover.

The application of dusts, potassium cyanate (X 1) and sodium cyanamid (X 10) did not control the younger vegetation and thus material treated in this way was unsuitable for combining.

In the harvesting of the treated plots, Table II, 5, a misunderstanding which resulted in pooling of the seed from the plots treated with potassium cyanate spray and sodium cyanamid spray prevented recording of individual plot yields. When the combined yields of the two treatments were compared to the yield of the swathed plot however, a 20% increase in yield per acre

was noted. As no material was left until a killing frost, no comparison with this method was possible. It was also noted that a much cleaner sample of seed was obtained from the chemical pre-harvest treatment of alsike clover than from the swathed material.

### Alfalfa, 1950

### Table II, 6

### Plot Trials

| Chemical | Rate, lb./ acre | Gallons of $H_2O$ applied /acre | % top-killing (Av. of 2 reps) |
|---|---|---|---|
| Potassium cyanate (X 1) spray | 10 | 40 | 25 |
| | 15 | 40 | 85 |
| | 25 | 40 | 100 |
| Potassium cyanate (X 1) spray + 1 g. Dreft | 10 | 40 | 75 |
| | 15 | 40 | 100 |
| | 25 | 40 | 100 |
| Potassium cyanate (X 1) dust | 40 | -- | 0 |
| | 50 | -- | 5 |
| | 75 | -- | 20 |
| Potassium cyanate (X 1) blend dust | 80 | -- | 10 |
| | 100 | -- | 15 |
| | 150 | -- | 50 |
| Sodium cyanamid (X 5) spray | 60 | 40 | 85 |
| | 80 | 40 | 98 |
| | 120 | 40 | 100 |

Table II, 6 (Continued). Plot Trials

| Chemical | Rate, lb./ acre | Gallons of $H_2O$ applied /acre | % top-killing (Av. of 2 reps) |
|---|---|---|---|
| Sodium cyanamid (X 5) spray + 1 g. Dreft | 60 | 40 | 100 |
| | 80 | 40 | 100 |
| | 120 | 40 | 100 |
| Sodium cyanamid (X 10) dust | 80 | -- | 15 |
| | 100 | -- | 25 |
| | 150 | -- | 45 |
| Potassium cyanate (X 1) spray | 5 | 40 | -- |
| | 7½ | 40 | -- |
| + | 12½ | 40 | -- |
| Sodium cyanamid (X 5) spray three days later | 30 | 40 | 20 |
| | 40 | 40 | 60 |
| | 60 | 40 | 100 |
| Potassium cyanate (X 1) spray | 5 | 40 | -- |
| | 7½ | 40 | -- |
| + | 12½ | 40 | -- |
| Potassium cyanate (X 1) blend dust three days later | 40 | -- | 15 |
| | 50 | -- | 50 |
| | 75 | -- | 70 |
| Potassium cyanate (X 1) spray | 5 | 40 | -- |
| | 7½ | 40 | -- |
| + | 12½ | 40 | -- |
| Sodium cyanamid (X 10) dust three days later | 30 | -- | 12 |
| | 40 | -- | 45 |
| | 75 | -- | 90 |
| Potassium cyanate (X 1) dust | 40 | -- | -- |
| | 50 | -- | -- |
| + | 75 | -- | -- |
| Sodium cyanamid (X 10) dust three days later | 40 | -- | 10 |
| | 50 | -- | 20 |
| | 75 | -- | 40 |
| Sodium cyanamid (X 5) spray | 30 | 40 | -- |
| | 40 | 40 | -- |
| + | 60 | 40 | -- |
| Sodium cyanamid (X 10) dust three days later | 30 | -- | 35 |
| | 40 | -- | 75 |
| | 75 | -- | 100 |

Table II, 7

| Chemical | Rate, lb./ acre | Gallons of $H_2O$ applied /acre | % top-killing 14 days later |
|---|---|---|---|
| Potassium cyanate (X 1) spray | 2½ | 40 | 0 |
| | 5 | 40 | 20 |
| | 10 | 40 | 60 |
| | 15 | 40 | 90 |
| Potassium cyanate (X 1) spray + 1 g. Dreft | 2½ | 40 | 15 |
| | 5 | 40 | 35 |
| | 10 | 40 | 85 |
| | 15 | 40 | 95 |

Table II, 8

| Chemical | Rate, lb./ acre | Gallons of $H_2O$ applied / acre | % top-killing (2 reps.) 14 days later |
|---|---|---|---|
| Potassium cyanate (X 1) spray | 6 | 40 | 50 |
| | 12 | 40 | 90 |
| Potassium cyanate + 1 g. Duz | 6 | 40 | 95 |
| | 12 | 40 | 100 |
| Potassium cyanate + 1 g. Tide | 6 | 40 | 80 |
| | 12 | 40 | 90 |
| Potassium cyanate + 1 g. Fab | 6 | 40 | 90 |
| | 12 | 40 | 100 |
| Potassium cyanate + 1 g. Vel | 6 | 40 | 65 |
| | 12 | 40 | 90 |
| Sodium cyanamid (X 5) spray | 30 | 40 | 80 |
| | 60 | 40 | 90 |
| Sodium cyanamid + 1 g. Duz | 30 | 40 | 80 |
| | 60 | 40 | 90 |
| Sodium cyanamid + 1 g. Tide | 30 | 40 | 85 |
| | 60 | 40 | 100 |
| Sodium cyanamid + 1 g. Fab | 30 | 40 | 100 |
| | 60 | 40 | 100 |
| Sodium cyanamid + 1 g. Vel | 30 | 40 | 80 |
| | 60 | 40 | 90 |

Table II, 9

| Chemical | Gals./ acre | Gals. of emulsion /acre | % top-killing |
|---|---|---|---|
| QXS - 16C* | 20 | - | 80 |
| | 60 | - | 95 |
| | 80 | - | 100 |
| QXS - 16C + 1 g. Dreft | 10 | 100 | 40 |
| | 20 | 100 | 80 |
| | 60 | 100 | 95 |
| QXS - 16C + Potassium cyanate 1½ lb./acre | 2 | 100 | 0 |
| QXS - 16 C + Potassium cyanate 3 lb./acre + 1 g. Dreft | 2 | 100 | 15 |
| QXS - 16C + Potassium cyanate 6 lb./acre + 1 g. Dreft | 2 | 100 | 25 |
| QXS - 16C + Potassium cyanate 1½ lb./acre + 1 g. Dreft | 5 | 100 | 10 |
| QXS - 16C + Potassium cyanate 3 lb./acre + 1 g. Dreft | 5 | 100 | 20 |
| Potassium cyanate 6 lb./acre + 1 g. Dreft | 5 | 100 | 60 |
| Potassium cyanate (X 1) spray + 1 g. Dreft | 1½ lbs. | 100 gal/a. | 2 |
| | 3 lbs. | 100 gal/a. | 12 |
| | 6 lbs. | 100 gal/a. | 25 |

* QXS - 16C contained 76% aromatic hydrocarbons. Courtesy Imperial Oil Company.

## Alsike Clover, 1950

### Table II, 10

Field Trials (4-acre plots)

| Chemical | Rate, lb./ acre | Gallons of $H_2O$ applied /acre | % top-killing 14 days later |
|---|---|---|---|
| Potassium cyanate (X 1) spray + 1½ oz. Duz | 12 | 40 | 50 |
| Sodium cyanamid (X 5) spray + 1½ oz. Duz. | 30 | 40 | 75 |
| Swath | -- | -- | 100 |
| Frost | -- | -- | 50 |

### Table II, 11

Plot Trials

| Chemical | Gals./ acre | Gals. of emulsion /acre | % top-killing |
|---|---|---|---|
| QXS - 16C | 40 | - | 95 |
| | 60 | - | 100 |
| | 80 | - | 100 |

## Red Clover, 1950

### Table II, 12

### Plot Trials

| Chemical | Gals./ acre | Gals. of emulsion /acre | % top-killing |
|---|---|---|---|
| QXS - 16C | 20 | - | 45 |
| | 60 | - | 95 |
| | 100 | - | 100 |
| QXS - 16C + 1 g. Duz | 10 | 100 | 10 |
| | 20 | 100 | 45 |
| | 60 | 100 | 90 |
| QXS - 16C + Potassium cyanate 2 lb./acre + 1 g. Duz | 2 | 100 | 10 |
| QXS - 16C + Potassium cyanate 4 lb./acre + 1 g. Duz | 2 | 100 | 15 |
| QXS - 16C + Potassium cyanate 6 lb./acre + 1 g. Duz | 2 | 100 | 45 |
| QXS - 16C + Potassium cyanate 2 lb./acre + 1 g. Duz | 5 | 100 | 10 |
| QXS - 16C + Potassium cyanate 4 lb./acre | 5 | 100 | 20 |
| QXS - 16C + Potassium cyanate 6 lb./acre | 5 | 100 | 50 |
| Potassium cyanate (X 1) spray + 1 g. Duz | 2 lbs. | 100 gal/a. | 5 |
| | 4 lbs. | 100 gal/a. | 10 |
| | 6 lbs. | 100 gal/a. | 25 |

## Birdsfoot Trefoil, 1950

### Table II, 13

### Plot Trials

| Chemical | Rate, lb./ acre | Gals./ acre | % of maturity at time of treatment | dehiscence following treatment | % top-killing |
|---|---|---|---|---|---|
| Potassium cyanate (X 1) spray | 12 | 60 | | 7 days | |
| | | | 0 | 0 | |
| | | | 25 | 0 | |
| | | | 50 | 0 | |
| | | | 75 | 75 | |
| | | | 100 | 100 | 100 |
| | | | | 10 days | |
| | | | 0 | 0 | |
| | | | 25 | 0 | |
| | | | 50 | 18 | |
| | | | 75 | 95 | |
| | | | 100 | 100 | 100 |
| | | | | 14 days | |
| | | | 0 | 0 | |
| | | | 25 | 10 | |
| | | | 50 | 60 | |
| | | | 75 | 100 | |
| | | | 100 | 100 | 100 |

Table II, 13 (Continued). Plot Trials

| Chemical | Rate, lb./ acre | Gals./ acre | % of maturity at time of treatment | % dehiscence following treatment | % top-killing |
|---|---|---|---|---|---|
| Sodium cyanamid (X 5) spray | 60 | 60 | | 7 days | |
| | | | 0 | 0 | |
| | | | 25 | 0 | |
| | | | 50 | 0 | |
| | | | 75 | 0 | |
| | | | 100 | 80 | 100 |
| | | | | 10 days | |
| | | | 0 | 0 | |
| | | | 25 | 0 | |
| | | | 50 | 10 | |
| | | | 75 | 15 | |
| | | | 100 | 90 | 100 |
| | | | | 14 days | |
| | | | 0 | 0 | |
| | | | 25 | 10 | |
| | | | 50 | 30 | |
| | | | 75 | 52 | |
| | | | 100 | 98 | 100 |
| Sodium cyanamid (X 10) dust | 120 | -- | | 7 days | |
| | | | 0 | 0 | |
| | | | 25 | 0 | |
| | | | 50 | 10 | |
| | | | 75 | 80 | |
| | | | 100 | 100 | 5 |
| | | | | 10 days | |
| | | | 0 | 2 | |
| | | | 25 | 12 | |
| | | | 50 | 40 | |
| | | | 75 | 100 | |
| | | | 100 | 100 | 10 |

Table II, 13 (Continued). Plot Trials

| Chemical | Rate, lb./ acre | Gals./ acre | % of maturity at time of treatment | % dehiscence following treatment | % top-killing |
|---|---|---|---|---|---|
| | | | 14 days | | |
| | | | 0 | 68 | |
| | | | 25 | 85 | |
| | | | 50 | 95 | |
| | | | 75 | 95 | |
| | | | 100 | 100 | 25 |
| CHECK | | | 14 days | | |
| | | | 0 | 70 | |
| | | | 25 | 90 | |
| | | | 50 | 100 | |
| | | | 75 | 100 | |
| | | | 100 | 100 | - |

## Discussion

When alfalfa was treated with one chemical, followed three days later by the application of a second chemical, Table II, 6, there was a general increase in the amount of top-killing obtained. The final results however did not warrant the extra time and labor involved since comparable results could be obtained by the application of a single chemical treatment.

Potassium cyanate (X 1) spray at 10 pounds per acre with the addition of a spreader gave satisfactory results under the conditions of the trials, Fig. 3. Sodium cyanamid (X 5) spray at 60 pounds per acre, with the addition of a spreader, resulted in complete top-killing and it was later found that this chemical would give satisfactory results from applications as low as 30 pounds per acre, Fig. 1.

The dusts alone did not give satisfactory results, and the dusts in combination with sprays did not give an increase in top-killing to warrant this procedure.

When Dreft was added to potassium cyanate (X 1) spray it resulted in a reduction of the amount of chemical needed to obtain satisfactory results, Table II, 7, but the lowest practical rate of potassium cyanate (X 1) was 10-12 pounds per acre. The addition of Dreft to sodium cyanamid (X 5) permitted a reduction of the chemical to 30 pounds per acre.

In trial experiments using various detergents, Table II, 8, it was found that Fab, Duz, Tide and Vel followed in the order mentioned as to their effectiveness in increasing the efficiency of the chemical sprays.

The field trials on alsike clover indicated that potassium cyanate (X 1) spray at 12 pounds per acre plus 1½ oz. of Duz was sufficient to give satisfactory top-killing of the stand

treated, but that a longer period of time was required after the application as compared with sodium cyanamid (X 5) spray. The sodium cyanamid (X 5) at 30 pounds per acre plus 1½ oz. of Duz caused rapid top-killing sufficient to permit combine harvesting within five days.

Yields from each of the four-acre plots of this experiment were:

| | |
|---|---|
| Swathing ...................... | 392 lbs. |
| Potassium cyanate (X 1) spray.. | 471 lbs. |
| Sodium cyanamid (X 5) spray.... | 498 lbs. |
| Natural freezing .............. | 406 lbs. |

From these yield results it is evident that an increase in yield resulted from the application of a contact herbicide as a pre-harvest treatment of alsike clover. So not only can the time of harvest be controlled to a certain extent, but the increase in yield is further justification for pre-harvest treatment of alsike clover with a contact herbicide if the cost of the chemical is not prohibitive.

Sodium cyanamid (X 5) spray at 60 pounds per acre resulted in complete top-killing of birdsfoot trefoil and a delay in the mechanism of dehiscence. This would be an advantage in permitting direct combining before the occurrence of shattering.

Results from trial experiments using oil, QXS - 16C for pre-harvest top-killing of legumes indicated that a minimum of more than 20 gallons per acre is needed to obtain satisfactory results, Fig. 4, but equipment designed to efficiently apply smaller amounts of oil should be tested. The emulsions did not indicate any apparent benefits as compared with oil alone. The addition of potassium cyanate (X 1) as a fortifier gave results inferior to those obtained from lower amounts of oil alone.

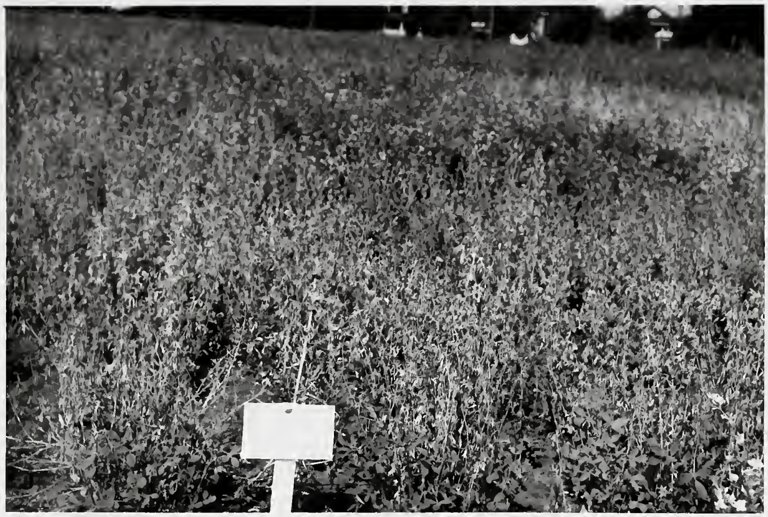

Fig. 1

Alfalfa plot treated with sodium cyanamid (X 5) spray 30 lbs. + 1 g. Dreft in 40 gallons of water per acre.

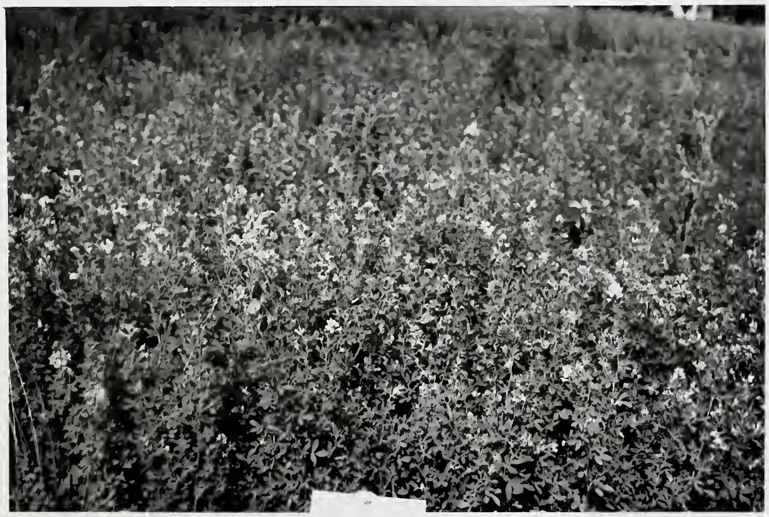

Fig. 2

Check plot of alfalfa.

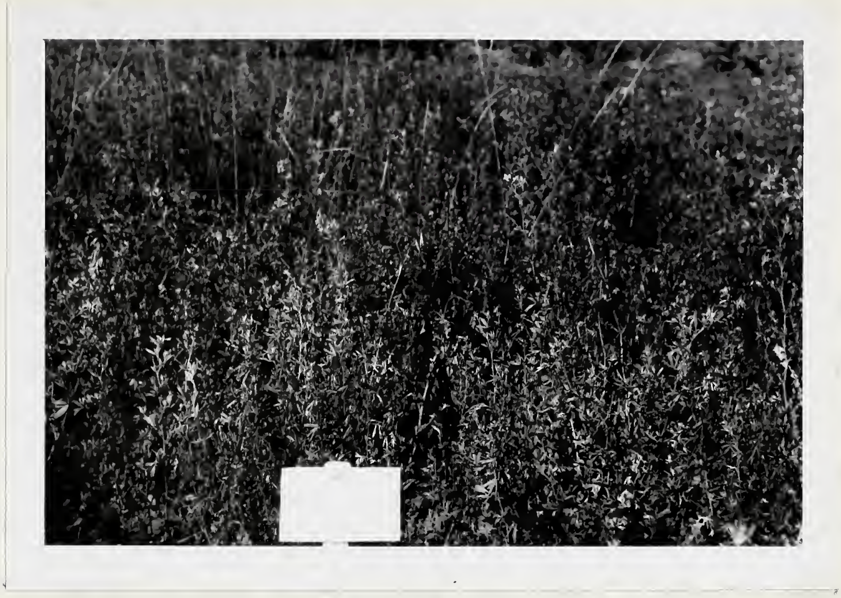

Fig. 3

Alfalfa plot treated with potassium cyanate (X 1),
10 pounds per acre + Dreft in 40 gallons of
water per acre.

Fig. 4

Alfalfa plot sprayed with oil QXS - 16C
at 60 gallons per acre.

## GENERAL DISCUSSION AND CONCLUSIONS

From the experimental results of three year's trials on the use of contact herbicides as pre-harvest treatment for legume seed crops, it is evident that the application of chemical as a spray resulted in a more satisfactory top-killing than that obtained from the application of the chemical as a dust. A more efficient method of applying the heavy cyanamid dusts may increase the amount of top-killing as compared with that reported in this section of the thesis. Alfalfa was the most resistant of the legumes treated. Red clover, because of its coarser stems, is not as susceptible as alsike clover. Potassium cyanate (X 1) spray at the rate of 15-20 pounds applied in 40 gallons of water per acre was satisfactory as a pre-harvest treatment to permit direct combining. The addition of a detergent permitted the reduction of this rate to 10-12 pounds per acre. Sodium cyanamid (X 5) spray at 60 pounds per acre resulted in sufficient top-killing to permit combining, and the addition of a detergent made feasible the reduction of this rate to 30 pounds per acre. Since sodium cyanamid (X 5) spray is very rapid in its action, this chemical may be useful for the pre-harvest treatment of birdsfoot trefoil. Such treatment by rapid killing of the seed

pod temporarily delays the mechanism of dehiscence making possible harvesting before occurrence of shattering. There is an apparent best time of application for maximum control. If the seed pod has reached the advanced stage of maturity the delay in dehiscence is very short, while the killing of an immature pod may affect the seed's viability. Further studies would establish the most suitable stage of maturity for treatment.

Observations made during the harvesting of legume seed indicated that it was not necessary to kill all of the top growth. If the leaves and seed head are killed, the stems may remain partially green and still be dry enough for direct combining. Figs. 6, 8, and 9, indicate the amount of top-killing satisfactory to permit direct combining. Figs. 5 and 7 show material prior to chemical top-killing.

Unlike the results obtained from pre-harvest top-killing of alsike clover, similar treatment of alfalfa did not increase the amount of seed harvested, but did permit direct combining and a partial control of the time of harvesting.

The use of oil, QXS - 16C as a pre-harvest top-killer was satisfactory at rates greater than 20 gallons per acre. The emulsions used did not bring about an improvement over results obtained with oil alone. Moreover the addition of potassium cyanate (X 1) as a fortifier did not permit a reduction in the amount of oil necessary to obtain satisfactory results.

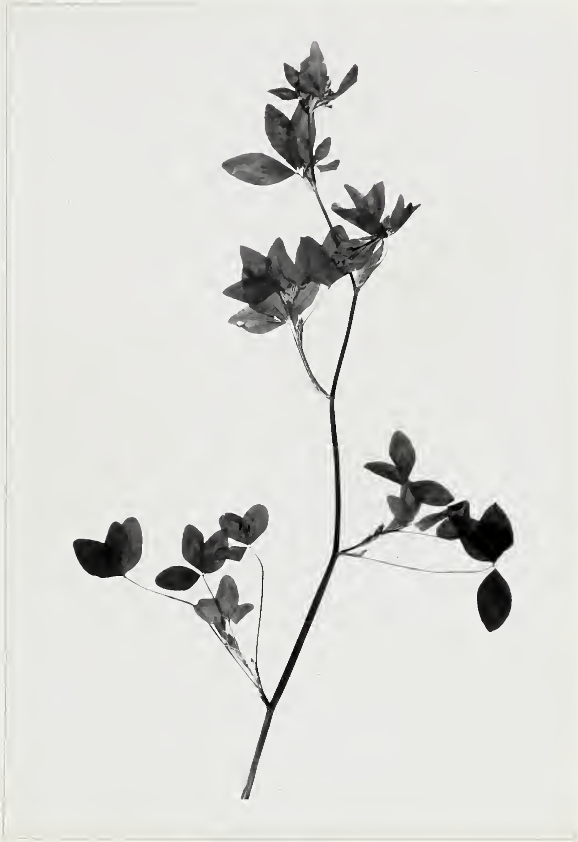

Fig. 5

Sample from check plot of red clover, *Trifolium pratense*.

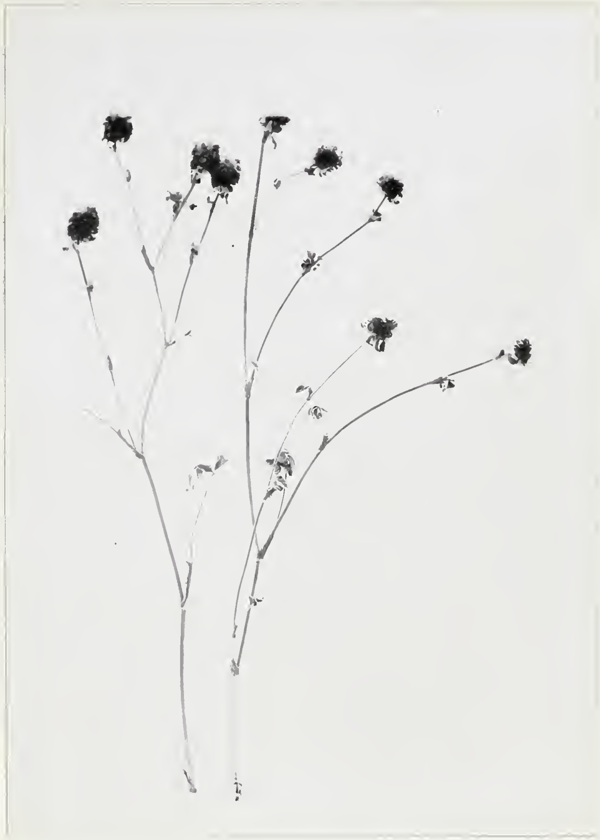

Fig. 6

Sample from plot of red clover, Trifolium pratense, treated with sodium cyanamid (X 5) at 30 pounds per acre + 1 g. Dreft in 40 gallons of water per acre.

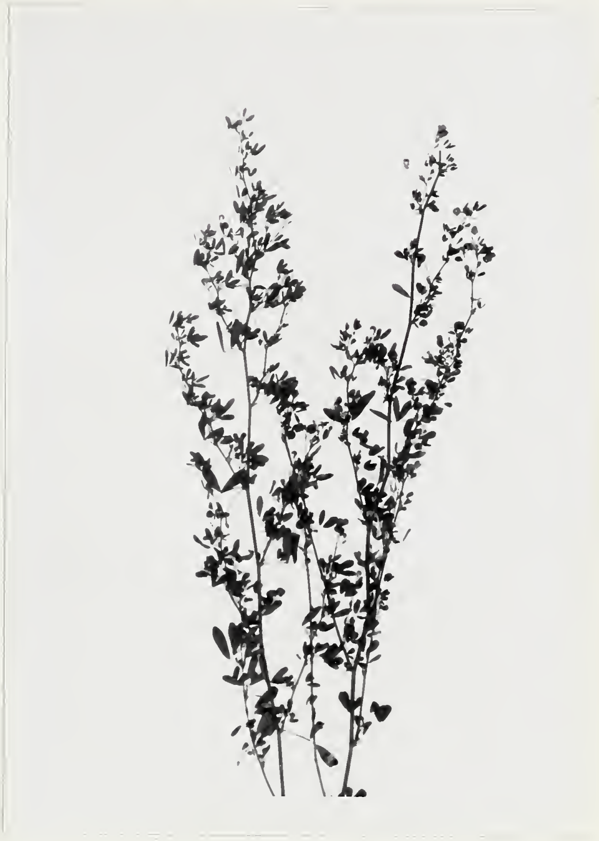

Fig. 7

Sample from check plot of alfalfa, *Medicago media*.

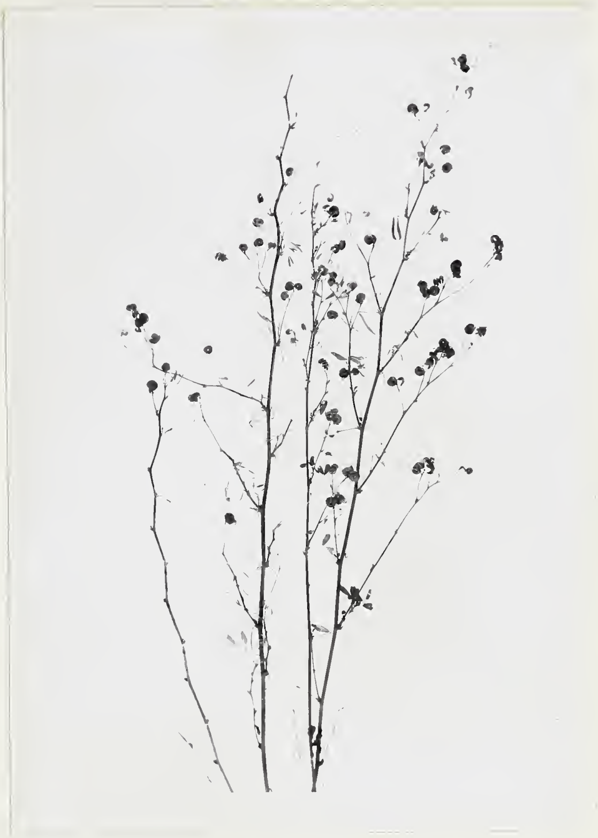

Fig. 8

Sample from plot of alfalfa,
Medicago media, treated with
sodium cyanamid (X 5) at
30 pounds per acre + 1 g. Dreft
in 40 gallons of water per acre.

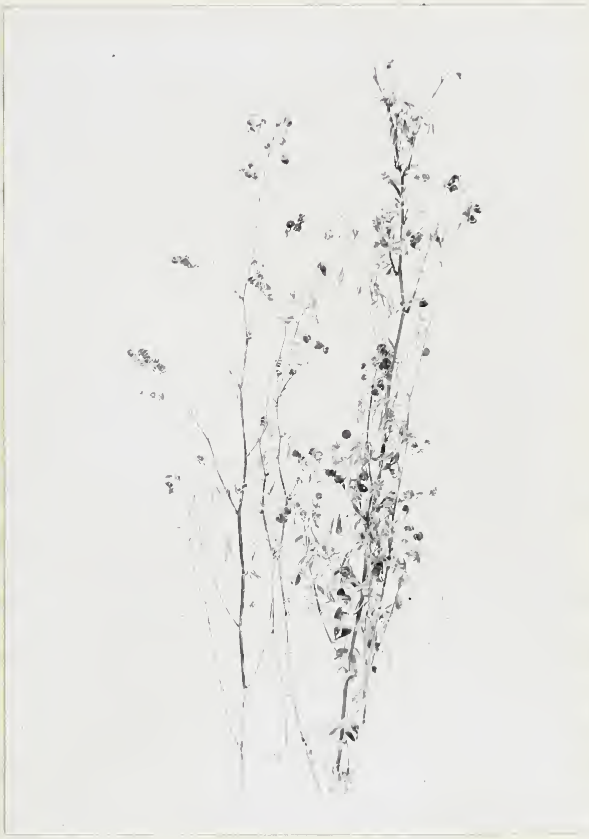

Fig. 9

Sample from plot of alfalfa, Medicago media, treated with potassium cyanate (X 1) at 10 pounds per acre + 1 g. Dreft in 40 gallons of water per acre.

# PART III

## THE EFFECTS OF CHEMICAL TOP-KILLING ON PLANT PHYSIOLOGICAL PROCESSES

### INTRODUCTION

When some of the plant organs are killed by chemical methods or by natural environmental factors such as frost, the responses of the surviving plant parts should be known in order that we may more fully assess the advantages and disadvantages of a particular field treatment. Injury to seed, injury to crown or root, depletion of root reserves, upsetting of physiological processes, changes in gross anatomy and many other problems require consideration.

Many contact herbicides are available for top-killing, but little is known of their effects on crop plants. It is known that when petroleum oils are used as selective herbicides in horticultural crops, off-flavors may result from its use at the wrong time. Excessive use of a contact herbicide may for

example, result in partial crown damage with a resultant decrease in yield of seed and forage.

The studies reported in the following pages were undertaken in an attempt to obtain a better understanding of plant responses to various treatments with herbicides.

## LITERATURE REVIEW

### Penetration

Fogg (12) reported on the entry of the contact herbicide, 3:5 dinitro-o-cresol into plant tissues. He stated that the poison may enter:

(a) as a solution or suspension through the stomata
(b) by diffusion through the cuticle and epidermal walls
(c) by diffusion as a gas through the stomata

In work with 3:5 dinitro-o-cresol there is very little evidence to show that entry is through the stomata. Fogg reported that

Wetzel and Ziegenspeck found that entry as aqueous solutions through the stomata occurred only under abnormal conditions. Crafts' (7) statement that sprays do not normally enter through the stomata was substantiated by Silversides (33).

Fogg considers that diffusion through the cuticle and epidermal cells is the most important method of entry and that this method is dependent upon the concentration of solution and the area contacted. He found that penetration was proportional to the concentration on the outside of the epidermis. Evidently the area covered was important since a reduction in area was noted in wilted leaves which were not damaged to the same extent as turgid leaves. The corrugations caused by the wilting gave some protection against the poison.

Fogg reported that diffusion through the stomata as a gas takes place only when the dust forms of herbicides are used. Some of the 3:5 dinitro-o-cresol may sublime at ordinary temperatures and penetrate as a gas, while at other times the gas may dissolve in the cuticular water and diffuse inward as a liquid.

Aslander (3) reported that the surface tension of sulphuric acid prevented its entry through the stomata, but when this surface tension was reduced, entry through the stomata was facilitated.

Hopp and Linder (17) indicated that a higher water tension inside the plant resulting from low humidity promoted the effectiveness of contact herbicides. At low humidity, however, the herbicide dried rapidly on the surface of the leaf and absorption was decreased. Moisture was needed to facilitate entry through the cuticle.

## Translocation

Aslander (3) found that there was no translocation of sulfuric acid when applied as a contact herbicide. Guy (16) and Thaxton and Jones (35) stated that no translocation occurred when Cyanamid contact-herbicides were used. Rich (30), working with potatoes, noted varying degrees of damage to tubers when the tops were killed with a contact herbicide, but stated that this damage resulted from the translocation of a substance already in the plant rather than from a movement of the chemical.

## Effects on Cell Constituents

### Germination

Ball et al (4) reported that petroleum oils had varying effects on the germination of seeds of different species, also that pre-soaking of the seed before applying the oil resulted in a increase in germination of some seeds, but a depression in others. MacDonald et al (23) stated that the treating of cotton seeds with dilute sulfuric acid resulted in an increase in germination and final yield of cotton. Too strong a concentration used for too long a time kills the seed.

DeFrance, Bell and Odland (10) utilized several fertilizers and chemicals to inhibit germination and weed growth by killing the seeds or by killing the young seedlings as they emerged from the testa. Abbott (1), and Welton and Carroll (41), agreed that cyanamid applied at the rate of one pound per square yard or 20 pounds per 1,000 square feet effectively prohibited the germination of annual weed seeds.

### Carbohydrates and Starch

Graber et al (13), working with alfalfa, found that any factor reducing the carbohydrate supply increased the percentage

of winter killing. Greathouse and Stuart (15) reported that in red clover it was not the carbohydrate supply that was so important but the respiration rate of the variety studied. A reduction in the carbohydrate supply however increased the amount of winter killing in all species because the reduced reserves were expended much faster. Mark (24) reported that while the carbohydrate supply is important in winter-hardiness, the genetical constitution of the plant is also a major factor. He stated that the winter hardy alfalfa plants had a higher nitrogen content than the non-hardy plants. Tysdal (38) found that the conversion of starch to soluble sugars resulted in an increase in protected enzymes which indicated an increase in winter hardiness. Kennard (18) reported that the hand picking of leaves from the trees of Montmorency sour cherry trees resulted in a reduction of winter-hardiness and the earlier this was done, the lower the resistance shown. This procedure lowers the amount of available carbohydrates.

Newton and Brown (27) stated that the adaptation of plants to resist frost appeared to depend on seasonal changes which gave the protoplasm stability. Sugar accumulation increased during the fall and a higher concentration was found in hardy varieties of winter wheat.

Grandfield (14) reported that a lowering of the carbohydrate and nitrogen content made the plant more susceptible to winter killing and that late fall cutting was detrimental to winter survival.

# MATERIALS AND METHODS

## Penetration

In the fall of 1948 plants of alfalfa, red clover and alsike clover were placed in two-gallon crocks and taken into the greenhouse. After the plants had attained complete first growth and had commenced second growth, the individual plants were treated in various ways using potassium cyanate (X 1) and sodium cyanamid (X 5) as sprays. The spray solution for each chemical contained one pound of chemical per gallon of water and where a spreader was included, soap at the rate of one ounce per gallon was added. Where individual leaves and stems were chosen for treatment, a paint brush was used in applying the solutions. At atomizer was used to spray the entire plants and the solution was applied to provide complete coverage.

Individual leaflets were studied under the microscope. The leaflets were first mounted in water and the solution introduced gradually from one side of the slide.

## Translocation

In one group of plants terminal leaflets of each leaf on a stem were painted with solutions of potassium cyanate (X 1) and sodium cyanamid (X 5) with and without the addition of soap. Individual plants were used for each treatment. On another group of plants a strip one inch wide was painted around the base of each stem. By means of a hypodermic syringe 0.5 cc. of solution of potassium cyanate (X 1) and sodium cyanamid (X 5) were injected into the stems of individual plants of alfalfa and red clover and into the crowns of healthy normal plants of alfalfa, red clover and alsike clover. Notes were taken on the second, sixth and fifteenth day after treatment.

## Effects on Cell Constituents

### Germination and Crown Damage

One hundred seeds each, of alfalfa, red clover and alsike clover were used in each of the following tests on the effects of potassium cyanate (X 1) spray on germination of the

treated seeds. The seeds were soaked in a solution containing one pound of chemical dissolved in one gallon water for 1, 6, 12 and 24 hours. They were then carefully washed and placed to germinate in Petri dishes. The check seeds were treated in a similar manner except the potassium cyanate was omitted.

Seeds of alfalfa, red clover and alsike clover were placed on fine mesh screens and sprayed with a solution containing potassium cyanate (X 1), one-half pound in one gallon of water. The seeds of each species were placed in Petri dishes without being washed, and one hundred seeds of each species were placed in a second set of Petri dishes after being carefully washed, and a check of one hundred seeds of each variety which had been sprayed with distilled water only were started in a third set of Petri dishes.

In addition samples of seed from each species were gathered each year from plots and fields treated with the various chemicals used each year. These samples were then forwarded to the Seed Analyst, Division of Plant Products, Calgary, Alberta, for germination tests.

As regards injury to vegetatively reproducing parts of the plant, notes were taken on crown killing resulting from the various treatments.

## Carbohydrates

### Total Sugars: -

In 1947, 47 rows of alfalfa were planted. The seed of each row had previously been gathered from individual plants of Ferax alfalfa which had shown a very high degree of self-fertility for several preceding generations. Careful observation during the following three years indicated a great deal of homozygosity between individual plants of each row and the parent line from which the seed had come. There was however a marked variation when comparing plants between rows. Five rows were selected from this group for treatment. It was hoped that there would be little plant variation between plants within rows. Each row was divided into plots containing four plants per plot. The following treatments were repeated in duplicate for the five rows:

(a) Top growth removed August 4, 1950, and roots harvested August 4, 1950.

(b) Top growth removed August 4, 1950, and roots harvested August 11, 1950.

(c) Top growth removed August 4, 1950, and roots harvested October 16, 1950.

(d) Top growth removed August 11, 1950, and roots harvested August 11, 1950.

(e) Top growth removed August 11, 1950, and roots harvested August 18, 1950.

The remaining portion of Row 3 received the following treatment beginning August 26, 1950.

(a) Top growth sprayed with potassium cyanate (X 1) spray at 12 pounds per acre in 40 gallons of water per acre with the addition of one gram of Dreft and roots harvested September 19, 1950.

(b) Top growth sprayed with sodium cyanamid (X 5) spray at 60 pounds per acre in 40 gallons of water with the addition of one gram of Dreft and roots harvested September 19, 1950.

(c) Top growth dusted with potassium cyanate (X 1) dust at 75 pounds per acre and roots harvested September 19, 1950.

(d) Top growth dusted with sodium cyanamid (X 10) dust at 75 pounds per acre and roots harvested September 19, 1950.

(e) Top growth removed and roots harvested September 19, 1950.

(f) Top growth removed and roots harvested October 16, 1950.

(g) Top growth left untouched and roots harvested September 16, 1950.

(h) Top growth left untouched and roots harvested October 16, 1950, following a killing frost October 15, 1950.

The sprays were applied with a knapsack sprayer and the dusts applied by means of a hand pump insecticide duster.

After harvesting, the roots were carefully washed and the crown removed. Ten inches of the root were then removed and placed in an oven at 100° C. The roots remained at this temperature for one hour and then the temperature was reduced to 60° C. for the next 48 hours. The roots were then removed and ground in a Wiley mill and the material divided into two portions for storage in air-tight containers. The material was later ball-milled for 24 hours.

Total carbohydrate analyses were carried out on the ball-milled material. Weinman's method (40) of preparation utilizing takadiastase for the breakdown of starch, dextrin and maltose to glucose was followed using 0.5 gram samples of air-dried material until final extract volume was reached. The semi-micro method of Underkofler et al (39) was used to measure reducing sugars reported here as glucose according to the graph shown in Fig. 10.

Starch: -

A quantitative method was used to determine what percentage of starch was present in the ball-milled material.

The method used by Pucher, Leavenworth and Vichery (28), for determining starch quantitatively appeared well suited for this purpose. A 0.200 gram sample was used. All determinations were carried out in quadruplicate.

## Protein

Nitrogen was determined using Kjeldahl-Gunning-Arnold method, with mercuric oxide as catalyst. Results were expressed as protein (N x 6.25) on a moisture-free basis.

## Phosphorous

Phosphorous was determined on the root material by the Truog-fusion method (36, 37). The standard curve, Fig. 11, was established from analytical data on preparations with known phosphorous concentrations.

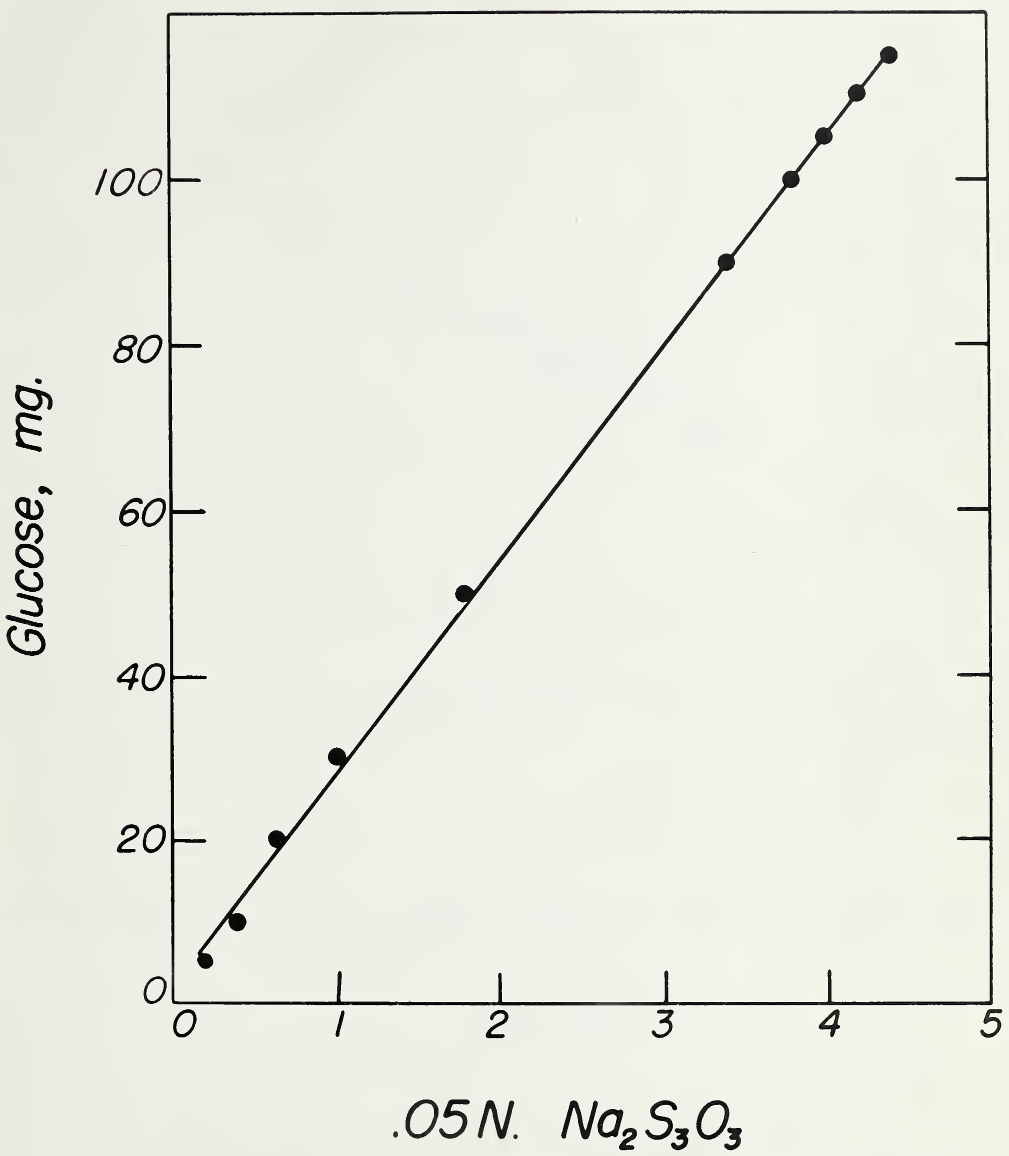

Fig. 10

Cc. of .05N $Na_2S_3O_3$ equivalent to copper reduced (W.B.-R).

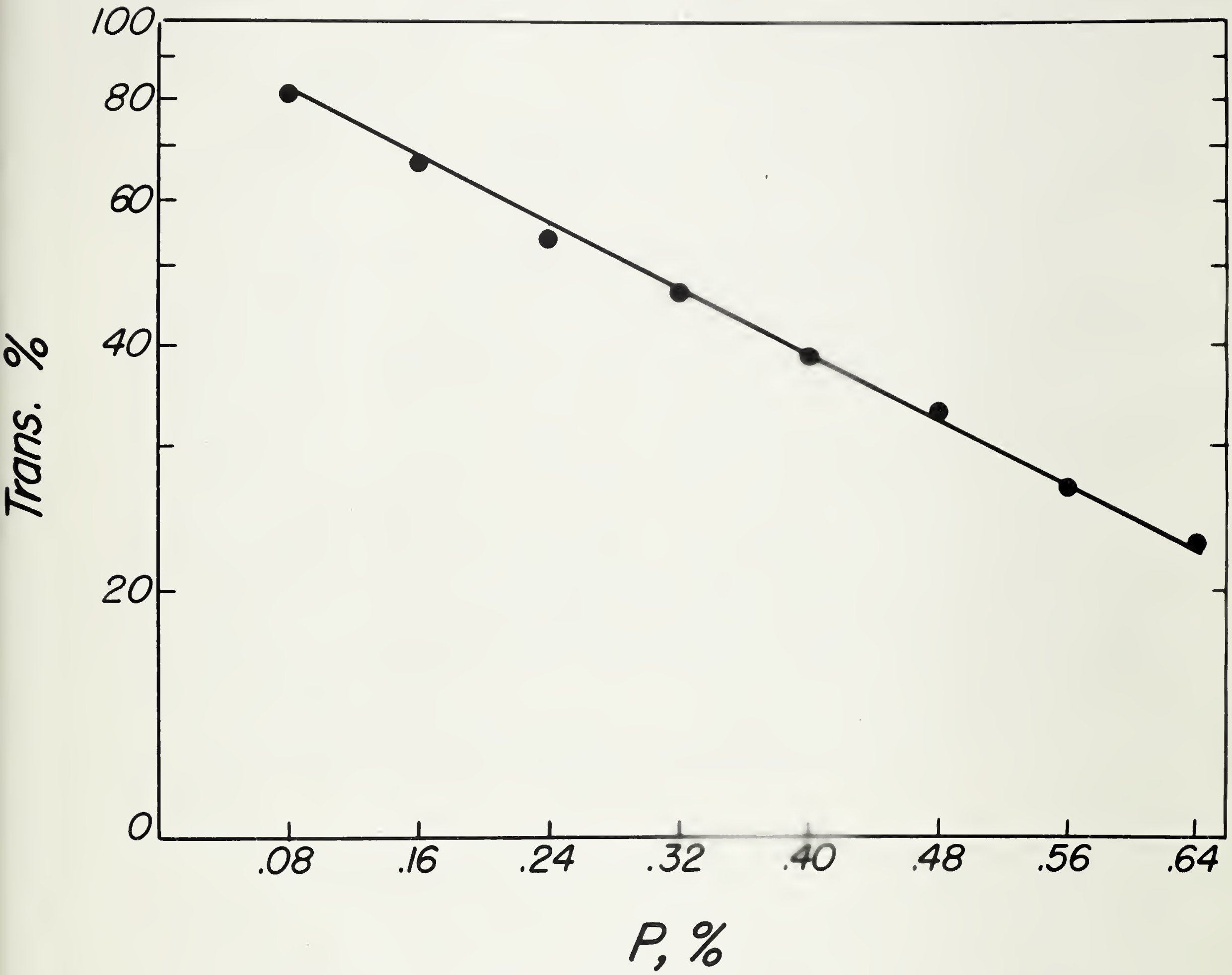

Fig. 11

Total phosphorous
($Na_2CO_3$ - Fusion + Truog colorimetric procedure)
705 mu. - slit about .04 mm.

## EXPERIMENTAL RESULTS

### Penetration

When the terminal leaflet of alfalfa leaves were painted with the solution of potassium cyanate (X 1) or sodium cyanamid (X 5), the solution tended to concentrate in numerous little globules on the leaflet surface. Penetration through the cuticle took place directly below each globlet regardless of its position on the leaflet. The sodium cyanamid penetrated the cuticle much more rapidly than did the potassium cyanate. The addition of soap to the solution prevented the formation of the globules and resulted in a much more uniform coverage and penetration of the cuticle followed by death to the entire leaflet.

When leaflets were placed under the microscope in a water mount and the solution of potassium cyanate (X 1) or sodium cyanamid (X 5) was introduced singly from one side of the cover slip, rapid and severe cell plasmolysis occurred, the protoplast finally disintegrating. It was noted that the stomata did not allow the solution to enter, but death of the guard cells occurred from diffusion of the chemical through adjoining killed cells. The chloroplasts of the guard cells clumped together rapidly and remained so after death of the tissue. Diffusion

from cell to cell was very slow and after a few cells this movement stopped until more solution was added.

The rate of penetration was most rapid in alsike clover, followed by red clover and alfalfa respectively. The pubescent nature of red clover tended to act as a protector against a water solution, but the addition of soap overcame this resistance.

## Translocation

Within two days after the application of the chemical solutions to terminal leaflets, death occurred. Six days after the application the two lateral leaflets still remained normal and there was no evidence of chlorosis or necrosis. Fifteen days after treatment the same condition prevailed, there being no evidence of translocation of herbicides from the terminal leaflet to the lateral leaflets or petioles.

On the second day after application of the solutions the one inch strips of treated tissue were necrotic and the material above the strips was showing evidence of wilting. The plants which had been treated with sodium cyanamid showed a more

advanced stage of wilting. On the sixth day following the date of application, death of all material above each strip was noted. There was no evidence of death below the point of application. Microscopic studies showed that all phloem and parenchymatous tissues were dead. The cells at point of application showed evidence of protoplasmic destruction while the cells above this area showed symptoms of being cut off from water supply. Apparently the death of the cells at point of contact of the solution prevented movement of water past this area. The cells below the area treated appeared normal and functioning at the time of observation. There was no apparent translocation of the chemical up or down the stem. Studies on the fifteenth day after application confirmed the observations made after the sixth day.

Observations two days after injections into normal crowns showed that all vegetation above the point of injection was dead. Six days after the injections, death had occurred to that part of the crown receiving the solution, but untouched portions still continued normal growth. Fifteen days after injections decay of that portion of root below the point of injection and of that part of the crown receiving the injection was noted. The root, crown and top growth of the remaining part of the plant appeared normal however, thus indicating that no translocation took place.

## Effects on Cell Constituents

Tables III, 1 to III, 3, illustrate the effects of various chemical treatments upon seed germination and plant crowns.

Table III, 1

| Chemical | Hours of soaking | Alfalfa | Red clover | Alsike clover | Alfalfa | Red clover | Alsike clover |
|---|---|---|---|---|---|---|---|
| Potassium cyanate (X 1) | 24 | 0 | 0 | 0 | 60 | 92 | 87 |
| | 12 | 0 | 3 | 4 | 71 | 89 | 90 |
| | 6 | 16 | 22 | 26 | 69 | 92 | 84 |
| | 1 | 63 | 84 | 86 | 68 | 88 | 91 |

Table III, 2

| | % germination (unwashed) | | | % germination (washed) | | | % germination (check) | | |
|---|---|---|---|---|---|---|---|---|---|
| Chemical | Alfalfa | Red clover | Alsike clover | Alfalfa | Red clover | Alsike clover | Alfalfa | Red clover | Alsike clover |
| Potassium cyanate (X 1) | 0 | 0 | 0 | 62 | 81 | 86 | 68 | 88 | 87 |

Seeds which were washed following spraying showed no injurious effects of the chemical treatment on germination whereas the chemical retained on the seed coats of the unwashed seeds prohibited germination.

Table III, 3

| | | % germination | | | % crown killing | | |
|---|---|---|---|---|---|---|---|
| Chemical | Rate, lb./ acre | Al-falfa | Red clover | Alsike clover | Al-falfa | Red clover | Alsike clover |
| Check | - | 86 | 91 | 92 | - | - | - |
| Potassium cyanate (X 1) spray | 10 | 89 | 92 | 94 | 0 | 0 | 0 |
| Sodium cyanamid (X 5) spray | 60 | 87 | 89 | 90 | 0 | 0 | 0 |
| | 100 | 89 | 91 | 92 | 0 | 0 | 0 |
| Potassium cyanate (X 1) dust | 80 | 84 | 89 | 94 | 0 | 0 | 0 |
| | 120 | 90 | 92 | 93 | 0 | 0 | 0 |
| Sodium cyanamid (X 10) dust | 80 | 88 | 93 | 91 | 0 | 0 | 0 |
| | 120 | 87 | 90 | 92 | 0 | 0 | 0 |
| Oil QXS-16C | 60 | 86 | 89 | 89 | 0 | 0 | 0 |
| | 80 | -- | -- | 86 | 0 | 0 | 0 |
| | 100 | 89 | 90 | -- | 0 | 0 | 2 |
| Oil QXS-16C + $H_2O$ to 100 gals. | 60 gals | 87 | 92 | -- | 0 | 0 | 0 |
| Oil QXS-16C + 6 lbs. K CnO (X 1) | 2gals. | 91 | 94 | -- | 0 | 0 | 0 |
| Oil QXS-16C + 6 lbs. K CnO (X 1) | 5gals. | 89 | 93 | -- | 0 | 0 | 0 |

Table III, 4 and III, 5, illustrate the effect of contact herbicides upon root constituents.

Table III, 4

Combining Two Replicates

| Row | Treatment of top growth | Roots harvested | % total carbohydrate per 0.500 g. sample | % starch | % protein | % phosphorous |
|---|---|---|---|---|---|---|
| | Cut | | | | | |
| 1 | Aug. 4 | Aug. 4 | 17.5 | 5.60 | 16.6 | |
| | 4 | 11 | 8.9 | 1.01 | 16.3 | 0.152 |
| | 11 | 11 | 21.4 | 4.27 | 15.6 | 0.152 |
| | 11 | 18 | 15.5 | 2.40 | 16.1 | |
| 2 | Aug. 4 | Aug. 4 | 16.7 | 6.70 | 16.1 | |
| | 4 | 11 | 17.5 | 0.56 | 16.4 | |
| | 11 | 11 | 21.6 | 6.97 | 16.7 | 0.140 |
| | 11 | 18 | 10.1 | 1.60 | 16.8 | |
| 3 | Aug. 4 | Aug. 4 | 22.0 | 7.20 | 17.3 | |
| | 4 | 11 | 14.7 | 1.30 | 16.4 | |
| | 11 | 11 | 20.2 | 8.60 | 16.7 | 0.128 |
| | 11 | 18 | 10.0 | 2.25 | 18.1 | |
| 4 | Aug. 4 | Aug. 4 | 4.8 | 8.50 | 16.9 | |
| | 4 | 11 | 16.7 | 0.56 | 16.8 | |
| | 11 | 11 | 22.0 | 7.87 | 16.5 | 0.116 |
| | 11 | 18 | 8.6 | 0.90 | 16.1 | |
| 5 | Aug. 4 | Aug. 4 | 24.2 | 4.70 | 16.9 | |
| | 4 | 11 | 15.5 | 1.78 | 16.8 | |
| | 11 | 11 | 25.5 | 3.90 | 16.9 | 0.116 |
| | 11 | 18 | 10.1 | 0.70 | 17.3 | |
| 3 | X 5 spray Aug. 26 | Sept. 19 | 22.5 | 1.70 | 20.8 | 0.200 |
| 3 | X 1 spray Aug. 26 | Sept. 19 | 20.9 | 5.60 | 15.7 | 0.200 |
| 3 | X 10 dust Aug. 26 | Sept. 19 | 20.6 | 13.5 | 16.6 | 0.160 |
| 3 | X 1 dust Aug. 26 | Sept. 19 | 24.5 | 2.70 | 16.7 | 0.168 |
| 3 | Swathed Aug. 26 | Sept. 19 | 12.0 | 4.50 | 16.6 | 0.216 |
| 3 | Aug. 26 swathed | Oct. 16 | 23.4 | 1.69 | 16.3 | 0.168 |
| 3 | Frost killed Oct. 15 | Oct. 16 | 22.3 | 1.10 | 19.9 | 1.152 |
| 3 | Check | Sept. 19 | 15.5 | - | 16.1 | 0.218 |

## Table III, 5

### Combined Results

| Treatment of top growth | Roots harvested | % total carbohydrate per 0.500 g. sample | % starch/ 0.200g. sample | % protein | % phos-phorous |
|---|---|---|---|---|---|
| 1950 | | | | | |
| Cut | | | | | |
| Aug. 4 | Aug. 4 | 20.92 | 5.6 | 16.75 | |
| Aug. 4 | Aug. 11 | 14.56 | 1.04 | 16.51 | .152 |
| Aug. 11 | Aug. 11 | 22.15 | 6.31 | 10.52 | .130 |
| Aug. 11 | Aug. 18 | 10.86 | 1.57 | 16.92 | |
| X 5 spray Aug. 29 | Sept. 19 | 22.5 | 1.7 | 20.87 | 0.20 |
| X 1 spray Aug. 29 | Sept. 19 | 20.9 | 5.6 | 15.72 | |
| X 10 dust Aug. 29 | Sept. 19 | 20.6 | 8.5 | 16.62 | |
| X 1 dust Aug. 29 | Sept. 19 | 24.5 | 2.7 | 16.75 | |
| Swath Aug. 29 | Oct. 16 | 23.4 | 1.10 | 16.31 | 0.168 |
| Swath Aug. 29 | Sept. 19 | 12.0 | 4.5 | 16.6 | 0.216 |
| Check | Sept. 19 | 15.5 | 5.4 | 16.13 | 0.218 |
| Frost killing | Oct. 16 | 23.4 | 1.69 | 19.91 | 0.152 |
| 1949 | | | | | |
| X 5 | Afterfrost | 21.6 | 1.1 | 19.95 | .216 |
| Check | After frost | 20.6 | 1.3 | 19.37 | .164 |

## Carbohydrates

There was a marked decrease in the total carbohydrates Table III, 4, following removal of top growth after seed set by the first growth. When the plant remained uncut until September 19, 1950, it was found that the total carbohydrates were also low, this probably being due to support of flowering of the second growth. In four out of the five rows tested, there was a marked difference in the amount of total carbohydrates present at time of harvesting between rows, which indicated an inter-plant variation. Duplicate results, not shown in Table III, 4, indicated no apparent difference between plants within rows.

Swathing of the plants resulted in a decrease in total carbohydrates but when sufficient growing time elapsed before frost, there was a rebuilding of total carbohydrates.

### Starch: -

When top growth was removed there was a rapid conversion of starch to soluble carbohydrates, Table III, 5. At time of frost very little reserve starch was found while the total carbohydrates were high. The use of the rapid top-killer sodium cyanamid (X 5) produced results closely paralleling frost treatment. There was a rapid conversion of reserve starch to soluble sugar. The slower

top-killers did not affect the reserve starch to the same extent. Swathing of the plants resulted in a reduction of total carbohydrates but not a marked reduction in stored starch.

Protein: -

There was little variation in the protein content of the roots except when frost occurred or a rapid top-killer was applied. Both of these treatments resulted in an increased protein content.

Phosphorous: -

There was only a minor variation in phosphorous content of the roots but a slight increase in the per cent of phosphorous was noted, Table III, 5, in treated material as compared with the percentage present when frost-killing occurred.

## DISCUSSION

It is evident from the results of the experimental trials that penetration of Cyanamid contact herbicides is through the cuticle of the leaf and not through the stomata. As the chemicals used are heat stable, it is very unlikely that there is any penetration by means of vapor. The addition of a spreader increases the area covered by the spray and results in a greater surface being contacted and therefore a larger proportion of killed material. There was no apparent translocation of the chemical. Any movement was the result of very limited diffusion in all directions. Application of the chemical in dust form necessitates the presence of water before the chemical becomes active.

The only plant crown damage that was evident occurred through the application of the oil QXS - 16C at the rate of 100 gallons per acre, Table III, 3. At this rate, only two plants per hundred were killed. Sodium cyanamid (X 5), applied at 100 pounds per acre, retarded some of the crown buds, but these later became active and grew vigorously.

From germination results it was evident that germination of harvested material treated with petroleum oil and Cyanamid contact herbicides was not decreased, Table III, 3. The

seed pods apparently prevent the penetration of the contact herbicide to the seed coat and therefore threshed seed is free from chemical injury. If the Cyanamid is applied to the seed, sufficient of the chemical remains on the testa to prevent germination or kills the radicle as it emerges from the seed coat, Table III, 2. In laboratory tests, washing the seed to remove the chemical, Table III, 2, permitted normal germination. Seeds soaked in a solution of the chemical resulted in a decrease in germination, Table III, 1. The magnitude of the decrease increased with time of soaking and the amount of penetration.

It may safely be concluded that the pre-harvest treatment of the legume seed crops studied did not affect the germination of the harvested seed.

Preliminary studies on total sugars, starch and protein content of alfalfa roots indicated that there was very little variation within closely related plants, but with the exception of protein content, a larger difference did occur when unrelated plants were compared.

There was a marked decrease in the total carbohydrates one week after top growth of alfalfa was removed. This undoubtedly resulted during the initiation of new growth which followed the removal of the original green material. There was also a rapid conversion of stored starch to soluble carbohydrates.

Following the swath treatment, soluble carbohydrates decreased and had killing frosts been experienced prior to September 19, 1950, the roots would likely have entered the winter with marked diminution of food reserves. Full recovery of available carbohydrates was noted October 16, 1950. This indicates that swathing of top material must be carried out early enough in the season to permit replenishment of diminished food reserves before a killing frost occurs.

The application of a rapid acting top-killer, sodium cyanamid (X 5) spray, reacted in a manner resembling that of a killing frost. There was no apparent decrease of total carbohydrates three weeks following treatment and most of the stored starch was converted into soluble sugars during this period. This conversion was also noted following the frost-killing treatments. The use of a slower acting killer did not induce conversion of the reserve starch to soluble sugar. No loss of total carbohydrates was noted three weeks following treatment. In view of the above mentioned results that indicate conversion of stored starch to soluble sugars following the treatment of alfalfa with a fast acting top-killer, there appears to be a possibility of similar achievement with economic advantage in the production of root crops such as sugar beets.

Protein content of the rapidly top-killed alfalfa closely approximated that of the frost killed material while amounts of protein in material from other treatments were relatively lower.

The phosphorous content of the roots of alfalfa treated with sodium cyanamid appeared to be slightly higher than that found in the roots of the frost-killed material.

Continued study of the effects of contact herbicides upon chemical constituents of surviving plant organs appears to be warranted in further efforts to clarify the physiological and practical significance of the changes which take place.

## SUMMARY AND CONCLUSIONS

1. There is reason to believe that within the limits of this investigation Cyanamid contact herbicides may be useful for:
   (1) The weeding of first-year stands of legume seed crops. Potassium cyanate (X 1) spray at 10 - 12 pounds per acre plus a spreader in 40 gallons of water per acre, and sodium cyanamid (X 5) at 30 pounds per acre plus a spreader in 40 gallons of water per acre proved the

most successful. In order to obtain satisfactory results the weeds must not have reached the flowering stage at time of treatment.

(2) The pre-harvest treatment of legume seed crops to permit direct combining. Sodium cyanamid (X 5) at 60 pounds per acre in 60 gallons of water or at 30 pounds per acre plus a spreader in 60 gallons of water gave satisfactory results. Potassium cyanate (X 1) spray at 10 - 12 pounds per acre plus a spreader in 40 gallons of water also proved satisfactory on alsike clover.

2. Certain petroleum oils used at not less than 20 gallons per acre, were successfully used as a pre-harvest treatment for legume seed crops in preparation for direct combining.

3. No effects on germination were found when Cyanamid contact herbicides or petroleum oils were used as top-killing agents on legume seed crops.

4. Treatment of top growth with Cyanamid contact herbicides is no more detrimental to root reserves of alfalfa than any other practice currently used on legume seed crops.

5. The rapid acting sodium cyanamid (X 5) spray resulted in chemical changes within the alfalfa root which approximated the changes brought about by low temperatures and top-killing frosts.

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